

Cosmic Evolution and Galaxy Formation: Structure, Interactions, and Feedback
ASP Conference Series, Vol. 3 × 10⁸, 2000
J. Franco, E. Terlevich, O. López-Cruz, and I. Aréxaga, eds.

Chemical and dynamical evolution in gas-rich dwarf galaxies

Simone Recchi, Francesca Matteucci

*Dipartimento di Astronomia, Università di Trieste, Via G.B. Tiepolo
 11, 34131 Trieste, Italy*

Annibale D’Ercole

*Osservatorio Astronomico di Bologna, Via Ranzani 1, 44127 Bologna,
 Italy*

Abstract. We study the effect of a single, instantaneous starburst in a gas-rich dwarf galaxy on the dynamical and chemical evolution of its interstellar medium. We consider the energetic input and the chemical yields originating from SNeII, SNeIa and intermediate-mass stars. We find that a galaxy resembling IZw18 develops a galactic wind carrying out mostly the metal-rich gas. The various metals are lost differentially and the metals produced by the SNeIa are lost more efficiently than the others. As a consequence, we find larger $[\alpha/\text{Fe}]$ ratios for the gas inside the galaxy than for the gas leaving the galaxy. Finally we find that a single burst occurring in primordial gas (without pre-enrichment), gives chemical abundances and dynamical structures in good agreement with what observed in IZw18 after ~ 29 Myr from the beginning of star formation.

1. Introduction

Blue compact dwarf galaxies (BCD) are gas-rich systems experiencing an intense star formation. These galaxies have very simple structures, small sizes and are very metal poor. For these reasons, BCD are excellent laboratories to investigate the effect of a starburst on the chemical and dynamical evolution of the interstellar medium (ISM).

Previous dynamical and chemical studies of these galaxies have suggested the existence of a ‘differential galactic wind’, in the sense that after a starburst event these objects would loose mostly metals (ref. Mac Low & Ferrara 1999; D’Ercole & Brighenti 1999; Pilyugin 1992, 1993; Marconi et al. 1994). However, in none of these studies, detailed chemical and dynamical evolution was taken into account at the same time. The aim of this paper is to include the effects (both energetic and chemical) of type II and type Ia SNe in a detailed dynamical model.

2. Model description

We consider a rotating gaseous component in hydrostatic isothermal equilibrium with the gravitational and the centrifugal forces. The potential well is given by the sum of a spherical, quasi-isothermal dark halo and an oblate King profile. The resulting gas distribution resembles that observed in IZw18 in a region $R \leq 1$ Kpc and $z \leq 730$ pc, which we call ‘galactic region’.

To describe the evolution of the ISM we solve a set of time-dependent, hydrodynamical equations, with source terms describing the rate of energy and mass return from the starburst. Mass is returned mostly by SNeII and intermediate-mass stars (IMS), while the energy is injected essentially by SNe. For the first time, here we take into account also the contribution by SNeIa. These supernovae start to explode after 29 Myr, at the end of the SNII activity, occurring with the explosion of stars with $8 M_{\odot}$ (see Nomoto, Thielemann & Yokoi 1984).

Following Bradamante et al. (1998), we suppose that SNeII convert only 3% of their explosion energy into thermal energy of the ISM. SNeIa, instead, do not suffer radiative losses because they explode in a medium heated and diluted by the previous SNeII activity and release all their energy into the ISM.

We solve an ancillary set of equations which keep track of the evolution in space and time of some specific elements lost by stars, namely H, He, C, N, O, Mg, Si, Fe. The production of these elements are obtained following the nucleosynthetic prescriptions from various authors: Woosley & Weaver (1995) for the SNeII, Renzini & Voli (1981) for IMS and Nomoto et al. (1984) for SNeIa. For more details, see Recchi et al. (2000).

The standard model, called M1, has a gaseous mass inside the galactic region of $\sim 1.7 \times 10^7 M_{\odot}$ and a mass of gas turned into stars of $\sim 6 \times 10^5 M_{\odot}$, in reasonable agreement with the observations of IZw18. We run other two models obtained by reducing the burst luminosity of a factor 0.6 (model M2) and by reducing the mass of gas of a factor 0.25 (model M3). Moreover, we consider four nucleosynthetic options: we consider an initial abundance of the ISM of $Z = 0$ and $Z = 0.01 Z_{\odot}$ and two possible values for the mixing length parameter $\alpha_{RV} = 0$ and $\alpha_{RV} = 1.5$. In the models with $\alpha_{RV} = 1.5$ we can produce N in a primary way in IMS.

3. Results

In model M1 a classical bubble develops as a consequence of SNII explosions (see Fig. 1). It expands faster along the z direction, where the ISM density gradient is steeper. The SNII wind stops before the possible breakout, and the subsequent SNIa wind is not strong enough to expand the cavity further. The size of the bubble thus does not change for nearly 300 Myr, although the shape varies irregularly because of the Kelvin-Helmholtz instabilities along the interface between the hot cavity and the surrounding gas. After ~ 340 Myr the expanding ISM is diluted enough and the hot bubble finally breaks out through a funnel. Most of the SNII ejecta remain locked into the bubble wall inside the galaxy, while the SNIa elements, ejected later, are easily channelled along the funnel. Iron is mostly produced by SNeIa and, when the breakup occurs, most

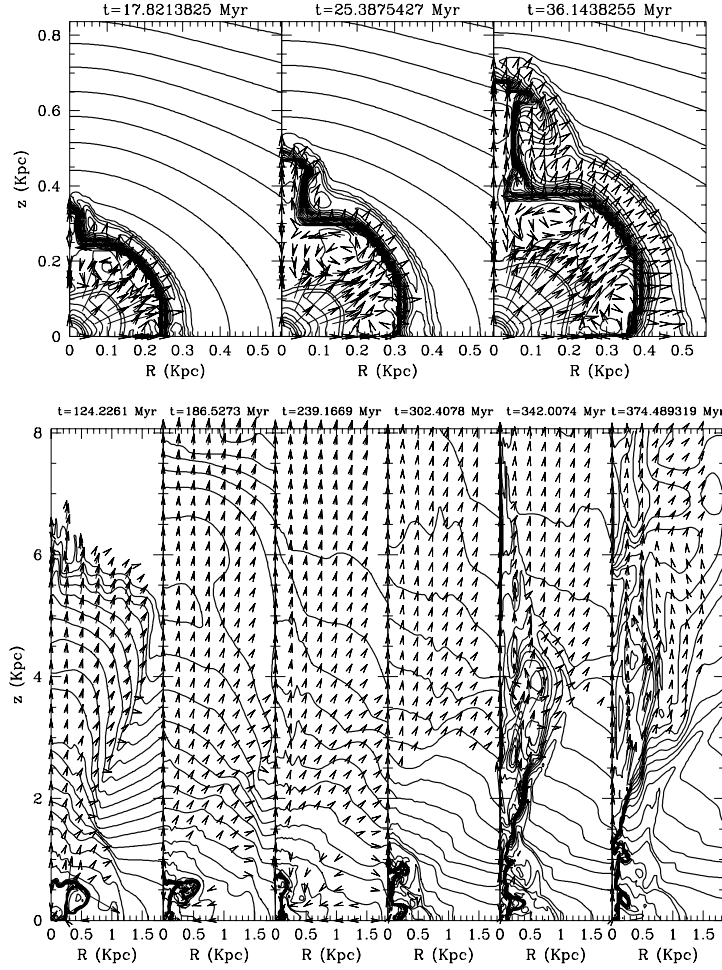


Figure 1. Isodensity curves (in logarithmic scale) and velocity field for the model M1 at various burst ages.

of it is lost. Thus the gas $[\alpha/\text{Fe}]$ ratio results lower outside the galaxy than inside (see Fig. 2).

After ~ 29 Myr [the burst in IZw18 is evaluated to be 15 - 27 Myr old by Martin (1996)] the galactic abundances found in this model are in good agreement with those observed in IZw18 once the nucleosynthetic prescriptions with $Z = 0$ and $\alpha_{\text{RV}} = 1.5$ are assumed. At this time a substantial fraction of N is produced by IMS in a primary way. An initial metallicity of $Z = 0.01 Z_{\odot}$ (simulating a pre-enriched burst), worsens the agreement between data and model results. Also the observed dimensions of the dynamical structures are in reasonable agreement with our result after ~ 29 Myr.

Models M2 and M3 have similar dynamical behaviours. However, due to the different quantity of metals produced and gas mass lost, their abundances are overestimated (M3) or underestimated (M2) compared to IZw18. We also

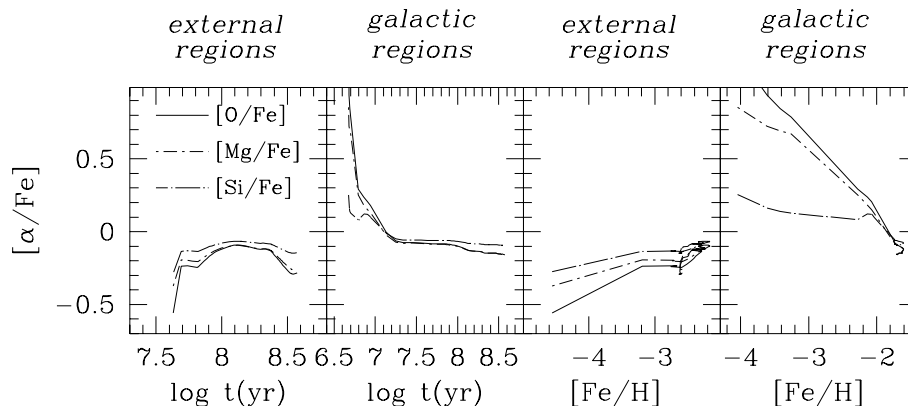


Figure 2. Predicted $[\alpha/\text{Fe}]$ vs. time and vs. $[\text{Fe}/\text{H}]$ for both expelled gas and ISM for the model M1

run a model similar to M1 but with a 100% efficiency of SNeII in heating the gas. In this case the galaxy results devoided of gas 450 Myr after the burst, at variance with the substantial amount of ISM in IZw18.

References

- Bradamante, F., Matteucci, F. & D'Ercole, A. 1998, *A&A*, 337, 338
 D'Ercole, A. & Brighenti, F. 1999, *MNRAS*, 309, 941
 Mac Low, M.-M. & Ferrara, A. 1999, *ApJ*, 513, 142
 Marconi, G., Matteucci, F. & Tosi, M. 1994, *MNRAS*, 217, 391
 Martin, C.L., 1996, *ApJ*, 465, 680
 Nomoto, K., Thielemann, F.K. & Yokoi K. 1984, *ApJ*, 286, 644
 Pilyugin, L.S., 1992, *A&A*, 260, 58
 Pilyugin, L.S., 1993, *A&A*, 277, 42
 Recchi, S., Matteucci, F. & D'Ercole, A. 2000, submitted to *MNRAS*
 Renzini, A. & Voli, M. 1981, *A&A*, 94, 175
 Woosley, S.E. & Weaver, T.A. 1995, *ApJS*, 101, 181